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TESTS OF RADIO RECEIVING SETS. I

Contents

Note.- This paper and the tests described herein are the result of work done in the Radio Laboratory of the Bureau of Standards by J.L.Preston, Physicist, Bureau of Standards, and H.F.Harmon, Radio Laboratory Assistant, U.S.Department of Agriculture. Acknowledgment is due Mr.L.C.F.Horle for assistance in the development of the methods used in these tests, and Messrs. N. Snyder, H.A.Wheeler and E.L.Hall for assistance in the laboratory measurements.

1. Purpose of Investigation.

This paper covers part of an investigation of the characteristics and performance of radio receiving sets, which was made at the Bureau of Standards in 1921-1922. The sets on which tests are herein described are regenerative sets using electron tube detectors and are of the type intended for such use as the reception of continuous wave signals from arc transmitting stations on wave lengths up to 5000 meters or more.

The assistance of the Bureau of Standards in determining the performance of radio receiving sets was requested by the Bureau of Agricultural Economics of the U.S.Department of Agriculture in connection with the reception of crop, market and weather reports which that Department is sending out through radio stations of the Post Office and Navy Departments and through public and private radio broadcasting stations. In order to make comprehensive tests of radio receiving sets it was necessary to develop methods of measurement and to formulate statements of the features which should be described as a result of an inspection of the mechanical and electrical design of the apparatus. The methods of measurement here used are described in detail in a publication of the Bureau of Standards now in preparation, entitled, "Tentative Methods of Testing Radio Receiving Sets." That paper contains further details of the testing methods used. It will probably be issued about July 1, 1923 as a Technologic Paper of the Bureau of Standards. Where the methods used on these particular sets differed from those described in the paper just mentioned, the aim of the test methods is to determine the degree in which a set has such desirable features as sensitivity, selectivity, convenience of operation, substantial construction, and effectiveness in covering the particular range of frequencies (wave lengths) which it is desired to receive.

It is not usually possible to secure the maximum of all desirable characteristics in a single piece of apparatus. For example, in order to secure the greatest possible selectivity it may be necessary to use a set which sacrifices ease of operation or some other desirable features. Commercial questions such as cost are also involved in the selection of apparatus for purchase.

At a conference in New York City on June 17, 1921, a representative group of American manufacturers of radio equipment were asked to submit to the Bureau of Standards receiving equipment suited to the type of reception described above. In this paper are given the details of the investigation of the mechanical and electrical characteristics of five of these receiving sets manufactured by four companies, constituting a majority of sets of this type on the market in 1921. Other papers in this series contain reports of tests of receiving sets of

several different types. The receiving sets included in this report were received by the Bureau of Standards in July, 1921. It may be noted that certain of these sets are, at the time of publication, obsolete, or have been modified in design by the manufacturers since these samples were received.

No consideration has been given to the possible existence of any patents which might cover devices or circuits used in any of the apparatus described. The Bureau of Standards can not give authoritative information concerning the patent situation with respect to a particular device.

The particular receiving sets studied are referred to by arbitrary reference numbers rather than by a statement of the manufacturers' names and type or model numbers. It is believed that the methods followed and the examples given in this report on the receiving sets included in this part of the investigation will be of assistance to manufacturers in the development of methods of testing and describing their own products and thus improving them. It is believed that purchasers will also be directly aided in deciding what features and characteristics to look for in the selection of apparatus.

To the various manufacturers and individuals who have helped in this work through furnishing sets for tests and in other ways, the Bureau expresses its thanks. Particular acknowledgment is due the Bureau of Agricultural Economics of the Department of Agriculture, which loaned assistants to carry on the laboratory work and cooperated in many other ways.

2. Outline of Inspections and Tests Made.*

*The tests are described in more detail in a Technologic Paper entitled, "Tentative Methods of Testing Radio Receiving Sets," which gives further details of the testing methods used. It is expected that this paper will be issued about July 1, 1923.

After a preliminary performance test to determine whether the receiving set as received was in proper operating condition, the following examinations and tests were made:

a. Circuit Diagrams.- The wiring diagram was checked or, if none was supplied, a diagram was made from the receiving set.

b. Circuit and Panel Arrangements.- Inspection was made of the exterior arrangements of the receiving set including description of the controls, knobs and switches.

c. Structural details.- The receiving set was examined to determine its ruggedness, the quality of material, quality of component parts, and quality of workmanship. In doing this the device was given a very close inspection to determine the

absolute and relative grades of materials from the mechanical viewpoint, with particular reference to the materials under mechanical strain, to the materials or parts which are likely to be subjected to the effects of moisture and to mechanical shocks and to the parts that are likely to wear in use.

d. Electrical Inspection.- The receiving set was examined to determine the quality of the component materials from the electrical viewpoint. This inspection was made with especial attention to the parts of the circuit which carry radio-frequency current and those which are under dielectric strain, and the protection of these parts from the effect of moisture.

e. Wave Frequency (Wave Length) Ranges.- A determination was made of the wave frequency (wave length) range of each receiving set when used with a "L" type antenna having a capacity of approximately 500 micromicrofarads. In addition to this, each receiving set was examined to determine whether generation can be maintained throughout the entire wave length range when used with the tubes supplied with the receiving set or with the type of tube specified for use with it.

f. Vibration Test.- This test was made to obtain information as to mechanical strength and ability to withstand shock in transportation.

g. Sensitivity.- This test was to determine the magnitude of the response in telephone receivers of the receiving set for a given voltage applied to the antenna.

h. Selectivity.- This test was to determine the ability of the receiving set to differentiate between signals of different frequencies.

i. Notes on Operation.- The receiving sets were connected to an antenna of measured constants and put into operation as specified by the manufacturer. The ease of operation, the precision and permanency of adjustment were noted.

3. Manufacturers' Specifications of Antenna, Wave Frequency Range, Electron Tubes, and Telephone Receivers.

Receiving set No. 1922-W.
Antenna - None specified.
Wave frequency (wave length) range stated,
300.0 to 25.0 kilocycles per second
1000 to 12,000 meters.
Electron tubes - Nos.R2822 and R2495 submitted.
Telephone receivers, -, 2200 ohms used.

Receiving set No. 1922-X.
Antenna - Capacity 500 to 2500 micromicrofarads, specified.
Wave-frequency (wave-length) range stated,
1200 to 57.5 kilocycles per second,
250 to 5200 meters.
Electron tube - No. R2495 used.
Telephone receivers, -, 2200 ohms used.

Receiving set No. 1922-Y.
Antenna - None specified.
Wave-frequency (wave length) range stated.
Electron tube - None specified (No.R2378 used).
Telephone receivers - None specified, -, 2200 ohms used.

Receiving set No. 1922-Z.
Antenna - None specified.
Wave-frequency (wave-length) range stated,
1200 to 43.5 kilocycles per second,
250 to 6800 meters.
Electron tube - No.R2614 used.
Telephone receivers, -, 2200 ohms furnished.

Receiving set No. 1922-XX.
Antenna - None specified.
Wave-frequency (wave-length) range stated,
1200 to 37.3 kilocycles per second,
250 to 8000 meters.
Electron tube - No.R2614 used.
Telephone receivers, - , 2200 ohms furnished.

4. Circuit Diagrams.

The circuit diagram of the five receiving sets included in this test are given in Figs. 1 to 5 inclusive.

5. Circuit and Panel Arrangements.

The receiving sets discussed in this report are similar in the following ways.

Each receiving set consists of two tuned circuits with variable inductive coupling between the circuits; both the inductance and the capacity of each circuit being independently variable.

Each receiving set is supplied with a continuously variable inductive coupling between the plate and grid circuits of the electron tubes so that a high degree of regeneration is possible. Controls are provided on the panels of each of the receiving sets for the variation of the capacities, the inductors, the coupling between the antenna, and secondary circuits, and the coupling between the secondary and plate circuits.

The condensers are supplied with find adjustment controls as well as controls for rapid and approximate adjustment. A safety gap is provided across the antenna and ground terminals of each receiving set.

The additional characteristics of the several receiving sets are given in the following paragraphs:

Receiving Set No. 1822-W.

A scheme of replacable inductors is used for the purpose of giving the receiving set almost unlimited wave frequency (wave length) range.

An electron tube detector and one stage amplifier with all controls and auxiliary apparatus are included in the receiving set.

No calibration scales are provided.

No provision is made for the use of a crystal detector.

The grid leak is mounted on the panel of the receiving set.

Variable grid and telephone condensers are provided with controls on the panel.

A switch is supplied whereby the antenna condenser may be placed either in series or in parallel with the antenna inductor.

A voltage divider is connected across the plate voltage supply batteries so that the plate voltage of the detector tube may be varied in differential steps.

A switch is mounted on the receiving panel for opening and closing the filament current circuit.

The inductors supplied are of the "honeycomb" type and are mounted on blocks with plugs and sockets which fit into corresponding sockets and plugs in the coil mounting provided on the top of the receiving set.

The plate voltage supply batteries are mounted inside of the receiving set.

The terminals for the connection of the antenna, ground and filament batteries are mounted on a laminated phenolic strip and are situated in the rear of the receiving set.

The connection to the telephone receivers is made through telephone jacks mounted on the panel.

Receiving Set No. 1922-X

No calibration scales are provided on the condenser dials, but the wave frequency (wave length) range of each secondary inductor step is engraved on the panel.

Provision is made for the use of a crystal detector for which terminals are supplied and for which a switch is used to quickly transfer the tuning system from the crystal detector to electron tube detector or vice versa.

A buzzer is supplied to assist in the adjustment of the crystal detector and for tuning the two circuits of the receiving set to resonance with one another.

An electron tube detector is provided for, all necessary auxiliaries, such as tube socket, filament rheostat being mounted in the receiving set. A door on the panel permits the convenient insertion or removal of the electron tube.

Receiving Set No. 1922-Y.

No electron tube is provided for in the tuner cabinet so that an electron tube control box is required.

No special provision is made for the use of a crystal detector.

No buzzer is supplied.

Calibration scales are provided for on the dials of the variable condensers; these dials are secured to the condenser knob and move under an indicator which is actuated by the inductor switch so that the wave length calibration of the receiving set may be marked on the condenser dial. The finish on the metal dials is such that this marking may be done in ink.

Provision is made for extending the wave frequency (wave length) range of the receiving set by the addition of loading inductors to the primary or secondary circuits for which purpose terminals are provided.

Receiving Set No. 1922-Z

Calibration scales are provided for on the dials of variable condensers; these dials are secured to the condenser knob and move under an indicator which is actuated by the inductor switch so that the wave length calibration of the receiving set may be marked on the condenser dial. The finish on the metal dials is such that this marking may be done in ink.

Provision is made for the use of a crystal detector for which terminals are supplied and switching arrangements employed so that the tuning system may be transferred quickly from the crystal detector to the electron tube detector or vice versa.

A switch is supplied for disconnecting the tuning condenser from the secondary inductor so that the tuning of the receiving set may be made broad for "stand-by" work. A buzzer is supplied for assistance in adjusting the crystal detector.

Receiving Set No. 1922-XX.

Calibration scales are provided for on the dials of variable dondensers; these dials are secured to the condenser knob and move under an indicator which is actuated by the inductor switch so that the calibration of the receiving set may be marked on the condenser dial. The finish on the metal dials is such that this marking may be done in ink.

Provision is made for an electron tube detector, all the necessary auxiliaries, such as electron tube sockets, filament rheostats, and filament ammeters, being mounted in the receiving set. A door on the panel allows the convenient insertion or removal of the electron tube.

Provision is made for the use of a crystal detector, and a switch is supplied so that the tuning system may be transferred quickly from the crystal detector to the electron tube detector or vice versa.

A variable telephone shunting condenser is supplied in the telephone circuit. This condenser serves as an additional control of regeneration when the electron tube detector is used. Provision is made for increasing the wave frequency (wave length) range of the receiving set by the introduction of loading inductors in both primary and secondary circuits for which purpose terminals are supplied.

A buzzer is supplied to assist in the adjustment of the crystal detector and in tuning the two circuits of the receiving set to resonance with one another.

6. Structural Details.

Of the five receiving sets discussed in this report, all but receiving set No. 1922-W are similar in general plan and in many details of construction. These receiving sets have their controls mounted on one surface of the receiving set, and all parts, such as condensers, inductors, tube mountings, switches, etc., are of the unit type, in that they are assembled completely on supporting brackets or insulating sub-bases which

are then secured to the panel. The connections are made either to the sub-bases or to the terminals strips which they carry. This method of construction is a very sturdy one, in that the units may carry their own bearings and are made free from the possible strains resulting from panel warping. The condensers are all of the balanced type and equipped with gear reducing controls except No. 1922-W. The inductors are all bank-wound on tubes of laminated phenolic insulating material and use high-frequency cable for the conductor. They are so arranged that the number of banks increases with the number of steps. They are all provided with means for minimizing losses in the unused sections. The condensers are supplied with large insulating end plates and insulating gear trains for fine adjustment control. The bearings are of brass on steel and are provided with a thrust collar on the sub-base.

The wiring between parts is made with sturdy copper conductor covered with varnished cambric tubing.

The paragraphs below give the distinguishing characteristics of this group of similar receiving sets.

<u>Receiving Set No. 1922-W.</u>

This receiving set uses removable inductors for the antenna circuit, the secondary circuit, and the electron tube plate circuit. The mounting for the inductor coils is placed on top of the receiving set as are the electron tubes and the spare inductor coils. Long mechanical links of a construction none too sturdy, connect the inductor mounting with the coupling control knobs on the panel. The inductor mounting itself is made up of moulded insulating parts supported on a brass casting. The latter is of extremely sturdy construction, but the moulded insulating parts, which are under serious strain when the inductors are being inserted or removed, are of rather doubtful strength. Since the bearings for the moving inductors are the insulating plates, this receiving set is to be criticised both from the standpoint of its probable lack of ability to withstand shock and the serious wear to which it may be subjected. The unit type of construction has been used only in the inductor mounting, and all other parts are supported directly by the panel and have their connections made to the panel. Where bearings are provided, they are located in the panel. Any warping of the panel, therefore, will tend to destroy the smooth operation of the moving parts. The condensers are balanced and their bearings are located in sturdy brass end plates insulated by means of rubber washers. The end thrust is taken up by adjustable bearings which may be moved axially. Fine adjustment of the condensers is secured by the use of an auxiliary moving condenser plate which is actuated by a small insulating control lever on the panel, and the setting of the condenser is indicated by a celluloid dial moving under the celluloid marker mounted

on the panel. No shielding of the parts is attempted, and the interconnections between the antenna circuit and secondary circuit appear to be made quite at random, the wires of either circuit coming very close to each other. The case, by its type of construction and material, is only fair in appearance and is not particular sturdy. The coil mounting and electron tubes are mounted on the wooden shelf of the case as are the plate-voltage supply batteries, and are subject to serious strain by shock and with the warping of the case.

Receiving Set No. 1922-X.

This receiving set differs from No. 1922-XX only in minor details. The special electrostatic shield winding is omitted from the coupling coil, and the tube socket is supported on soft rubber strips. The grid leak and grid condenser are conveniently mounted under the tube socket. No provision is made for varying the plate circuit high-frequency by-pass condenser.

Receiving Set No. 1922-Y.

This receiving set resembles No. 1922-XX except that no electron tube equipment has been included in the cabinet and that the coupling coil does not have the electrostatic shield winding.

Receiving Set No. 1922-Z.

A special coupling unit is provided so that an untuned secondary may be used, that is, when the secondary is used without the tuning condenser, exceptionally high coupling is secured. Resonant frequencies in the unused sections of the inductors in this receiving set are eliminated by the use of a disconnecting switch which rotates with the inductor switch.

The coupling control knobs are connected to the coupling coils through link motions, thus allowing the location of the coupling knobs without regard to the location of the coupling coils. In general, this receiving set is extremely sturdy throughout. Large condensers, large inductor forms, heavy conductors and generous bearings make it possible for it to withstand rather severe mechanical shock without harm.

Receiving Set No. 1922-XX.

This receiving set is typical of the group including, besides itself, receiving sets Nos. 1922-X and 1922-Y. These receiving sets are characterized by the fact that shielding of the receiving set proper and between parts has been resorted to for the elimination of electrostatic and electromagnetic coupling. To accomplish this the case and panel of the receiving set are completely lined with copper, and between the primary circuit

(consisting of the antenna, condenser and inductor) and the secondary circuit (consisting of its inductors and condenser together with electron tube and its auxiliaries) is placed a copper diaphragm, thus including the antenna circuit and the secondary circuit each in its own copper compartment. Electrostatic coupling between the primary inductor and secondary coupling inductor is eliminated by means of special wire shielding wound over the secondary coupling inductor. The inductors are provided with a switch which automatically short-circuits a portion of the unused inductor by the mere operation of the main control switch. Thus losses in the unused sections are minimized. The tube socket of this receiving set is mounted on brass springs well damped with cotton so that it may be as nearly shock-proof as possible. The filament rheostat is well ventilated and so designed that the resistance element is far removed from the panel. The two-way switch for changing the circuit from a crystal detector or a radio-frequency amplifier, to an electron tube detector is one of low capacity and low loss. In general high grade material is used, as well as thick panel, condenser end plates, and coil-supporting brackets.

7. Electrical Inspection.

In general the receiving sets are built up of materials of satisfactory electrical properties. With the exception of receiving set No. 1922-W, all parts are mounted on the phenolic insulating material panel and where conductors of widely different radio-frequency potential are supported on the panel or pass through it, the dielectric flux path is long and of small cross-section. This is typified by the condenser mountings of all but No. 1922-W; the opposite terminals of the condensers are removed from one another by approximately half the diameter of the insulating end plate while in No. 1922-W, only a thin hard rubber washer separates the moving plate shaft bearing from the brass end plates. Care is taken in all but No. 1922-W to keep the high potential grid lead far removed from other conductors of low potential and to keep the loss in intermediate material at a minimum. In No. 1922-W the leads from the several inductors are brought out quite indiscriminately and protected from one another only by the cotton covering of the conductor.

Laminated phenolic insulating material is used throughout for inductor forms, switch mountings, and tube socket mountings, in all of the receiving sets except No. 1922-W. In this receiving set, a wooden shelf is used as the support of several of the parts and moulded insulating material is rather generally used even where considerable dielectric and mechanical strain exists.

The circuits of all but No. 1922-W are carefully arranged insofar as relative positions and remoteness of the coils are

concerned, especial care being taken to reduce the capacitive coupling to a minimum, so that uncontrollable couplings are reduced or eliminated.

The conductor used in all but receiving set No. 1922-W is of high-frequency cable and is bank wound on laminated phenolic forms. The windings are impregnated with varnish. Only sufficient varnish appears to have been used on the Nos. 1922-X and 1922-Y to protect the winding from the absorption of moisture while on the Nos. 1922-Z and 1922-XX an excessive amount seems to have been used. It is to be noted that the presence of varnish on these coils is objectionable since it raises the dielectric loss considerably above that of a coil which is free from varnish and moisture, and is only justified in so far as it serves to keep moisture out of the coil. It should therefore not be used in any greater quantity than is required by this condition. The coils of receiving set No. 1922-W are wound on paper forms and are secured to the connecting plugs by means of fibre strips. Because of the hygroscopic nature of fibre this would be expected to seriously reduce the effectiveness of this receiving set in damp weather and in humid climates.

The stability of Nos. 1922-X and 1922-XX is improved by the inclusion of the electron tube and all its associated apparatus in the tuner cabinet itself so that it is free from external electrical influences. In addition, the inclusion of the tube and its auxiliaries in the cabinet will tend, through heating from the electron tube and the filament rheostat to keep the receiving set free from moisture.

The circuits and controls in all the receiving sets but No. 1922-W are arranged so that each control performs only one function in so far as that is possible. This is particularly true of the inductor, condenser, and coupling controls of Nos. 1922-X, 1922-Y and 1922-XX, and true to a lesser degree of No. 1922-Z. But this is not at all the fact in the case of No. 1922-W since the changing of coupling in this receiving set also changes the wave length to a large extent.

8. Wave Frequency (Wave Length) Ranges.

The wave frequency (wave length) ranges of the several receiving sets were determined* by operating them in connection with an actual antenna of approximately 0.0005 microfarad capacity and determining by means of a buzzer-driven wavemeter, the wave frequency (wave length) range of the combination of each inductor step of the primary and secondary with the antenna or

*See also the discussion in a separate Technologic Paper entitled, "Tentative Methods of Testing Radio Receiving Sets," which gives further details of the testing methods used. It is expected that this paper will be issued about July 1, 1922.

secondary condenser set at both minimum and maximum values. The wave frequency (wave length) ranges throughout which the receiving set will generate radio-frequency current were determined with this same setup. The procedure consisted of determining the setting at which the receiving set ceased to generate when maximum tickler coupling was used and measuring the wave frequency (wave length) at these settings. The data secured by these measurements are given in Tables 1 to 6.

From the wave frequency (wave length) range data secured as described above the band of wave frequencies (wave lengths) common to each of two successive inductor steps was determined. This common band is termed "over-lap." The ratio between the width of this band and the greater of the two limiting wave frequencies (wave lengths) of which it is the difference is termed the percentage overlap. The values of the percentage overlaps have been calculated and are given in Tables 1 to 6 with the wave frequency (wave length) range data. It is to be noted that a high percentage overlap is distinctly desirable in a secondary circuit and is almost essential in the primary circuit. In the secondary circuit a high percentage overlap is desirable since it allows certain bands of wave frequencies (wave lengths) to be obtained by two or more combinations of inductance and capacity and therefore may give the opportunity of choosing such values of inductance, capacity and resistance as will be best suited to the detector used or of such relative values as to give a choice of selectivity. This advantage applies also to the antenna circuit with the addition, however, that the maximum wave frequency (wave length) of any inductor tap is determined in the main by the antenna capacity, and the minimum by the series tuning capacity, thus the higher the percentage overlap, the smaller may be the capacity of the antenna without loss of wave length continuity in the primary circuits. The higher the percentage overlap the greater also will be the range of antenna capacities which may be used with the receiving set. The actual values of antenna capacity which may be used with the various receiving sets have not been determined.

Table 1.

Wave Frequency (Wave Length) Ranges of

Receiving Set No. 1922-W.

Coil	At minimum capacity		At maximum capacity		Overlap of		Percentage Over-lap of	
	Wave Frequency Kilocycles per second f	Wave Length Meters λ	Wave Frequency Kilocycles per second f	Wave Length Meters λ	Wave Frequency Kilocycles per second f	Wave Length Meters λ	Wave Frequency Kilocycles per second f	Wave Length Meters λ
Primary								
DL-200	373	800	180	1660	27	215	13	13
300	207	1445	94	3185	-	-	-	-
600	80.5	3700	38.1	7840	16.2	2340	29.8	30
1000	54.3	5500	26.5	11350	-	-	-	-
Secondary								
DL-150	479	625	154	1990	100.5	810	39.6	40.6
250	254.5	1180	74.5	4000	43.0	1440	36.6	36
500	117.5	2560	34.7	8600	41.3	4670	54.3	54
600	76	3930	25.45	11800				

Table 2

Wave Frequency (Wave Length) Ranges of

Receiving Set No. 1922-X.

Inductance tap	At minimum capacity		At maximum capacity		Overlap of		Percentage Overlap of	
	Wave Frequency Kilo-Cycles per second f	Wave Length Meters λ	Wave Frequency Kilo-cycles per second f	Wave Length Meters λ	Wave Frequency Kilo-cycles per second f	Wave Length Meters λ	Wave Frequency Kilo-cycles per second f	Wave Length Meters λ
Primary								
1	1155	260	675	443	145	79	17.7	17.8
2	820	364	364	820	131	216	26.5	26.3
3	495	604	197.5	1515	49.5	299	20.0	19.7
4	247	1216	132.0	2270	28	395	17.5	17.4
5	160	1925	63.5	4710				
Secondary								
1	1370	219	385	772	405	394	51.3	51.0
2	790	378	192	1562	315	972	62.2	62.2
3	507	590	151	1980	115	842	43.2	42.8
4	266	1132	84.5	3535	65.5	1535	43.6	43.4
5	150	2000	47.8	6250				

Table 3.

Wave Frequency (Wave Length) Ranges of

Receiving Set No. 1922-Y.

Inductance tap	At minimum capacity		At maximum capacity		Overlap of		Percentage Overlap of	
	Wave Frequency Kilocycles per second f	Wave Length Meters λ	Wave Frequency Kilocycles per second f	Wave Length Meters λ	Wave Frequency Kilocycles per second f	Wave Length Meters λ	Wave Frequency Kilocycles per second f	Wave Length Meters λ
Primary								
A	1015 [1]	295 [1]	720	415	170	80	19.1	19.3
B	890 [2]	335 [2]	520	575	160	135	23.5	23.5
C	680 [3]	440 [3]	284	1055	89	255	23.9	24.1
D	373 [4]	800 [4]	158	1890	42	380	21.0	20.0
E	200 [4]	1500 [4]	85	3510	29	80	25.4	24.8
F	114 [4]	2640 [4]	47.5	6300				
Secondary								
1	1155 [2]	260 [2]	600	500	205	130	25.5	26.0
2	805 [4]	370 [4]	339	880	186	310	35.4	35.3
3	525	570	214	1465	86	450	28.6	30.7
4	300	1015	115	2610	47	760	29.0	29.2
5	162	1850	63.2	4725	33.3	1625	34.5	34.4
6	965	3100	35.1	8480				

[1] With condenser set at 60°.
[2] With condenser set at 20°.
[3] With condenser set at 10°.
[4] With condenser set at 0°.

Table 4

Wave Frequency (Wave Length) Ranges of

Radio Receiving Set. No. 1922-Z.

Inductance tap	At minimum capacity		At maximum capacity		Overlap of		Percentage Overlap of	
	Wave Frequency Kilocycles per second f	Wave Length Meters λ	Wave Frequency Kilocycles per second f	Wave Length Meters λ	Wave Frequency Kilocycles per second f	Wave Length Meters λ	Wave Frequency Kilocycles per second	Wave Length Meters λ
Primary								
A	905	330	534	562	166	135	23.7	24.0
B	700	427	345	864	305	404	46.9	46.8
C	650	460	291	1030	289	516	49.8	50.0
D	580	514	253	1185	281	620	52.6	52.5
E	534	562	250	1200	84	306	25.1	25.5
F	334	894	164	1825	79	589	32.5	32.3
G	243	1236	112.2	2675	63.8	975	36.2	36.4
H	176	1700	85	3500	40	1100	32.0	31.5
I	125	2400	60	5000	26	1525	30.3	30.5
J	86	3475	39.3	7600				
Secondary								
1	1670	179	585	512	675	274	53.6	53.6
2	1260	238	312	962	398	541	56.0	56.0
3	710	421	156	1915	156	945	50.0	49.3
4	312	960	80	3730	167	2515	66.6	67.5
5	247	1215	60	5000	150	3775	71.4	71.5
6	210	1425	47.1	6350				

Table 5

Wave Frequency (Wave Length) Ranges of

Radio Receiving Set No. 1922-XX.

Primary

Inductance tap	At minimum capacity		At maximum capacity		Overlap of		Percentage overlap of	
	Wave Frequency Kilocycles per second f	Wave Length Meters λ	Wave Frequency Kilocycles per second f	Wave Length Meters λ	Wave Frequency Kilocycles per second f	Wave Length Meters λ	Wave Frequency Kilocycles per second f	Wave Length Meters λ
A	1070	*260	840	355	260.0	83	23.6	23.4
B	1100	272	520	575	105.0	98	16.8	17.0
C	625	477	282	1065	71.0	220	20.1	20.7
D	353	845	153.5	1950	32.5	340	17.5	17.4
E	186	1610	83.0	3600	24.0	800	22.4	22.2
F	107	2800	46.5	6425				

Secondary

Inductance tap	Capacity Minimum -0°		Capacity Maximum -180°		Overlap of		Percentage overlap of	
	Wave Frequency Kilocycles per second f	Wave Length Meters. λ	Wave Frequency Kilocycles per second f	Wave Length Meters λ	Wave Frequency kilocycles per second f	Wave Length Meters λ	Wave Frequency Kilocycles per second f	Wave Length Meters. λ
1	1360	220	517	579	518.0	290	50	50
2	1035	289	339	882	341.0	442	50	50
3	680	440	222	1350	137.0	515	38.1	38.1
4	359	835	123	2440	81.0	970	39.7	39.7
5	204	1470	71.5	4180	39.5	1470	35.6	35.
6	111	2710	38.7	7700				

* Condenser set at 50°.

Table 6

Summary of Wave Frequency (Wave Length) Ranges.

Receiving Set No.	Wave Frequency (Wave Length) Range Damped or Modulated		Continuous Wave Reception		Specified Wave Frequency (Wave Length) Range	
	Wave Frequency, Kilocycles per second f	Wave Length, Meters λ	Wave Frequency, Kilocycles per second f	Wave Length, Meters λ	Wave Frequency, Kilocycles per second f	Wave Length, Meters. λ
1922-W	373 to 25.5	800 to 11,800	373 to 25.5	800 to 11,800	300 to 25.5	1000 to 12,000
1922-X	1155 to 63.5	260 to 4710	1155 to 63.5	260 to 4710	1200 to 57.5	250 to 5200
1922-Y	1015 to 47.5	295 to 6300	980 to 63.5	305 to 4720	-	-
1922-Z	905 to 47.1	330 to 6350	600 to 47.1	500 to 6350	1155 to 44	260 to 6800
1922-XX	1070 to 46.5	280 to 6425	1070 to 46.5	280 to 6425	1200 to 37.4	250 to 8000

9. Vibration Test.

After it was determined that all parts were properly operative and correctly connected or after they had been made so, the five receiving sets were fixed, in turn, to the table of a vibration machine which subjects it to shock and vibration simulating the shocks of transportation.* The sets were subjected to this vibration for fifteen minutes each and then carefully inspected as to mechanical condition. None of these sets developed any defects during this test.

*A picture of the vibration machine used is given in a separate Technologic Paper entitled, "Tentative Methods of Testing Radio Receiving Sets," which it is expected will be issued about July 1, 1923.

10. Sensitivity Measurement.

The following method was used to determine the sensitivity of the receiving sets.* Since the precise determination by the ear of

*This method is discussed in more detail in a separate Technologic Paper entitled, "Tentative Methods of Testing Radio Receiving Sets," which it is expected will be issued about July 1, 1923.

the relative values of signal intensity is particularly difficult, measurements were made of the voltage across the telephone receivers produced by the received signal.

The measurement of this audio-frequency signal voltage in the plate circuit resulting from a modulated radio-frequency voltage induced in the antenna circuit was made by comparison of the plate circuit voltage with one available from a calibrated voltage divider supplied by an alternating-current of known value and having the frequency of the modulating voltage. An actual measurement of the two voltages was not made directly, however, but was accomplished by the comparison of the currents resulting in the output circuit of a two-stage audio-frequency amplifier. These currents were noted by means of a sensitive microammeter and crystal rectifier, coupled to the output circuit of the amplifier. Fig. 6 gives the schematic diagram of the circuits used in the measurements of sensitivity.

The conditions of measurement of the receiving sets in these tests were identical with those outlined in the description of the "change in plate current method" below except that measurements were here made with minimum and with maximum regeneration.

Having adjusted the receiving set for the best operating conditions the telephone current in the output of the amplifier was noted. The receiving set was then disconnected and the alternating-current supply was substituted for it. The value of the voltage applied to the input of the amplifier was then varied until the same current was obtained in the output circuit of the amplifier. The receiving set output signal voltage, under these conditions, was then equal to the known voltage applied to the input of the amplifier.

Measurements were made of the output voltage of each receiving set for the same input voltage at a wave frequency of 120 kilocycles per second (2500 meters) with the tickler coupling set at minimum and then at the highest value possible without "oscillation," or generation of current by the receiving set itself. The ratio of these two voltages is a measure of the regenerative amplification of which the set is capable. The output voltages and the voltage ratios mentioned above are given in Table 7.

It is to be noted that of the data given below, the values of the voltages measured on the non-regenerating receiving set are probably the best measures of sensitivity, since in actual practice they probably will be used in that condition most frequently.

The values of the voltages measured with maximum regeneration indicate the maximum sensitivities of the receiving sets when great care has been taken in their adjustments.

The ratios of the two voltages is not a measure of the capacity of the receiving set for regeneration, since the voltage measured in the non-regenerating condition is partially due to the inherent regenerative coupling. If any interpretation is to be made of these ratios it may be assumed that they are inverse measures of the inherent regeneration of the receiving sets.

Table 7

Sensitivity Measurements at 120 Kilocycles per second. (2500 meters).

Output voltages for constant input voltages.

Modulated (500 cycles) continuous-wave signal.

Receiving Set No.	Non-regenerating E volts	Regenerating E_1 volts	$\frac{E_1}{E}$
1922-W	0.071	0.322	4.55
1922-X	0.0348	0.1675	4.8
1922-Y	0.0314	0.233	7.4
1922-Z	0.098	0.226	2.3
1922-XX	0.0617	0.1783	2.90

11. Selectivity Measurement.

In order to determine the selectivity of the receiving sets used in this test the following method of measurement was used.*

*This method is discussed in more detail in a separate Technologic Paper entitled, "Tentative Methods of Testing Radio Receiving Sets," which it is expected will be issued about July 1, 1923.

The basis of this method lies in the fact that a radio receiving set should be capable of separating the signals from two transmitting stations which are operating simultaneously. Should it be simultaneously or successively excited by the application to the antenna circuit of two voltages of comparable magnitude and of slightly different wave frequencies (wave lengths), the difference between the two signal currents in the telephone receivers should be as great as possible.

As a numerical expression of the selectivity the ratio of the square root of the fractional change in telephone signal current

to the fractional change of the squared values of the wave length or frequency used. This is the sharpness of resonance, S, defined by the expression given below.

$$S = \sqrt{\frac{\dfrac{I_{tr} - I_t}{I_t}}{\dfrac{f^2 - f_r^2}{f_r\ f}}} = \sqrt{\frac{\dfrac{I_{tr} - I_t}{I_t}}{\dfrac{\lambda_r^2 - \lambda^2}{\lambda_r\ \lambda}}}$$

I_t is the current through the telephone receivers and f is the frequency and λ the wave length at which the measurement is made. Subscript r indicates the value at resonance.

In measuring the sharpness of resonance, the receiving set, with detector and auxiliaries, is connected to a real or artificial antenna, into which is induced an emf of constant magnitude. The wave frequency (wave length) is varied and the corresponding telephone signal currents are noted. The values of the wave frequencies (wave lengths) are determined directly from the calibration of the generator supplying the signal voltage to the antenna circuit or by measurement with a wavemeter, while the signal current in the telephone receivers is determined by use of a direct-current milliammeter.

For these measurements a low-power high-frequency generator was used to induce an emf in the antenna circuit and a portable milliammeter was used for measuring the current in the plate circuit of the detector tube.

The generator consisted of a 5-watt electron tube in connection with two inductors of the lattice or basket wound type, a coupling coil wound of high-frequency cable and a continuously variable air condenser. The scheme of connections is given in Fig. 7.

The receiving set under test was set up with the electron tube, telephone receivers, and values of filament current and plate voltage specified by the manufacturers. It was then tuned to resonance with the generator which was set at the frequency at which measurements were to be made. Tickler control was set at minimum and adjustment made for maximum telephone current as indicated by the milliammeter in the telephone circuit. The determination of the proper value of coupling for securing maximum selectivity at maximum telephone current was very carefully obtained. This depends on the constants of both the antenna and secondary circuits and upon the extraneous coupling between these two circuits. It is found that for very high coupling values the maximum value of telephone current may be secured, but for this condition it will be found that the system is resonant to two frequencies. The condition under which

measurement was made, however, was that when one resonant-frequency existed, and the coupling was adjusted to the maximum telephone current for this condition. The wave frequency (wave length) of the generator was then adjusted to values above and below resonance and readings of the telephone current were then taken for each of the above adjustments. The amplitude of the telephone signal current here used is the difference between the normal value of the plate current when there is no signal voltage on the grid, and the value of the plate current when the signal voltage is applied to the grid. These differences have been calculated from measurements taken on the receiving sets, at 300, 120 and 60 kilocycles per second (1000, 2500, and 5000 meters) and have been plotted as curves shown in Figs. 9-13 inclusive. From these curves the values of selectivity have been calculated by the expression given above. The particular value of sharpness of resonance used here is the one obtained by choosing the off-resonance value of the telephone current as half the value of telephone current at resonance. This is called $S_{\frac{1}{2}}$ on Figs. 8-13.

The sharpness of resonance of the five receiving sets are given in Tables 8, 9, 10, 11 and 12. Table 8 gives the sharpness of resonance of the receiving sets at 300 kilocycles per second (1000 meters) when used with a phantom antenna having 24 ohms resistance. Tables 9, 10 and 11 give the sharpness of resonance of the receiving sets at 300, 120 and 60 kilocycles per second (1000, 2500, and 5000 meters) when the resistance of the phantom antenna external to the receiving set was negligible. Table 12 summarizes Tables 9, 10 and 11. With the exception of Table 8 all the values of sharpness of resonance given were determined without resistance in the antenna circuit external to the receiving set so that the differences between the several receiving set circuits might be more easily observed. It is to be noted, however, that in actual use the inherent resistance of the antenna will make all these receiving sets less selective than indicated by Tables 9 to 12. It is impossible to say what antenna resistance will be used with the receiving sets, but the above measurements will probably serve to indicate their relative selectivities.

Table 8.

Sharpness of Resonance

Wave Frequency, 300 kilocycles per second, (1000 meters).

Added Antenna Resistance, 24 ohms.

Receiving Set	Selectivity	Control Settings of Receiving Set.					
		Primary		Secondary		Coupling	Tickler
		Inductance	Capacity	Inductance	Capacity		
1922-W	37.3	200T	18'	150T	29'	65°	100T - 90°
1922-X	33.8	3	9'	3	19.5'	35'	0'
1922-Y	32.6	C	45°	3	71°	110°	0°
1922-Z	35.0	C	26°	3	45°	30°	0°
1922-XX	45.1	C	49°	3	83°	50°	0°

Table 9

Sharpness of Resonance

Wave Frequency, 300 Kilocycles per Second (1000 meters).

Receiving Set	Selectivity	Control Settings of Receiving Set.					
		Primary		Secondary		Coupling	Tickler
		Inductance	Capacity	Inductance	Capacity		
1922-W	40.8	200T	17.5'	150T	29.0'	65°	100T°-90°
1922-X	51.3	3	9'	3	19.5'	35'	0'
1922-Y	75.4	C	46°	3	70°	70°	0°
1922-Z	134.3	C	25.5°	3	44°	20°	0°
1922-XX	65.8	C	50°	3	82°	40°	0°

Table 10

Sharpness of Resonance

Wave Frequency, 120 Kilocycles per Second, (2500 Meters).

Receiving Set	Selectivity	Control Settings of Receiving Set.					
		Primary		Secondary		Coupling	Tickler
		Inductance	Capacity	Inductance	Capacity		
1922-W	40.8	300T	25'	250T	45'	45°	150T-90°
1922-X	60	4	17½'	4	41.5'	40'	0'
1922-Y	62	E	23°	5	33	140°	0°
1922-Z	68.7	G	25°	5	39°	60°	0°
1922-XX	50.7	E	28°	5	51°	80°	0°

Table 11.

Sharpness of Resonance

Wave Frequency, 60 Kilocycles per Second, (5000 Meters)

Receiving Set	Selectivity	Control Settings of Receiving Set.					
		Primary		Secondary		Coupling	Tickler
		Inductance	Capacity	Inductance	Capacity		
1922-W	41.0	600T	21°	500T	45'	60°	300T-90°
1922-X	91.0	5	27'	5	64'	55'	0'
1922-Y	76.0	F	28°	6	52°	140°	0°
1922-Z	69.9	I	28'	6	103'	80	0
1922-XX	45.0	F	36°	6	74°	140°	0°

Table 12.

Summary of

Measurements of Sharpness of Resonance.

Receiving Set No.	Wave Frequency, 300 Kilocycles per second. (1000 m.) $S_{\frac{1}{2}}$	Wave Frequency, 120 Kilocycles per second. (2500 m.) $S_{\frac{1}{2}}$	Wave Frequency, 60 Kilocycles per second. (5000 m.) $S_{\frac{1}{2}}$
1922-W	40.8	40.8	41.0
1922-X	51.3	60.0	91.0
1922-Y	75.4	62.0	76.0
1922-Z	134.3	68.7	69.0
1922-XX	65.8	50.7	45.0

The high value of sharpness of resonance of receiving set No. 1922-Z at 1000 meters probably results from the fact that the inherent regeneration is greater at this wave length in this receiving set than in any of the others.

The low sharpness of resonance of receiving set No. 1922-W is probably not due to the use of the removable inductance coils. On the contrary the use of well designed removable inductance coils should make it possible to obtain higher selectivity at all wave lengths than can be obtained by other methods. The low selectivity is probably to be explained in the case of receiving set No. 1922-W by the dielectric and other losses due to the arrangement of parts, and by the use of small size solid wire in the coils used at the higher wave lengths.

12. Notes on Operation.

The several receiving sets described in this report were put into actual service at the field station and used for the actual reception of signals during which the ease of operation and permanence of adjustment was noted. A comparison of these characteristics indicates the following:

With the exception of the receiving set No. 1922-W the controls are systematic and almost identically arranged, the antenna circuit controls being located on the extreme left while the secondary circuit controls are on the extreme right, the coupling controls being either between or above the tuning controls. In receiving set No. 1922-W this arrangement is reversed so that the secondary inductance and the secondary condenser controls are on the extreme left while the primary inductance and primary condenser controls are on the extreme right. Where one of these receiving sets is used in connection with a transmitting set and closely adjacent to it, it is usually found more convenient to put the transmitting equipment on the left of the receiving set and separated from it only by the antenna transfer switch and to put the amplifier, if such an instrument is used, on the right of the receiving set so that it may be removed as far as possible from the transmitting set.

The number of adjustments required for broad tuning or for close tuning is about the same for any one of the receiving sets with the exception of No. 1922-W. For putting these receiving sets into operation at a particular wave frequency (wave length) seven or eight adjustments are necessary, while for retuning for comparatively small wave frequency (wave length) changes three or four readjustments are required. For great wave frequency (wave length) variations for which the value of the inductors must be changed two additional adjustments must be made in the case of each one of the receiving sets making a total of 5 or 6 readjustments. In all but receiving set No. 1922-W these adjustments are merely those of change of the inductor switch. In the case of the 1922-W, this change requires the removal of three inductors and their replacement by three others so that a longer time is required and the continuity of the operation of the receiving set is seriously interrupted by the noise in the telephone receivers incident to this change.

For broad tuning five to six adjustments are necessary when putting the receiving sets into operation and only two when making minor changes in wave frequency (wave length). All of the receiving sets allow about the same precision of adjustment since all of the variable condensers are equipped with similar fine adjustment controls and, with the exception of receiving set No. 1922-W, the inductor change mechanisms are very similar. Receiving sets Nos. 1922-X and 1922-XX have a slight advantage in that the inductor switches are equipped with a detent mechanism whereby they give the "feel" of being in proper position when they are so.

The permanence or stability of adjustment varies considerably between the several receiving sets. No. 1922-XX being most stable while No. 1922-W is the least so and this characteristic varies with the wave frequency (wave length) of operation. There are two types of stability involved in these considerations. One is that of stability of wave frequency (wave length) and the other

stability of generation. The former of these two is dependent upon the freedom of the apparatus from change in wave frequency (wave length) by causes external such as the position of the operator's hands, the motion of nearby metal masses, etc.; while the latter is dependent upon freedom of the apparatus from effect upon grid voltage by stray voltages or current impulses and to some extent upon the wave length stability. The former of these two has been attained in a rather high degree in receiving sets Nos. 1922-X and 1922-XX by means of very thorough shielding, so that it is found that the presence of the operator's hands near or on the receiving set controls, gives no change of beat note at the longer waves and only a minor effect in the extremely short waves. In the case of receiving set No. 1922-Y the wave frequency (wave length) stability is fairly satisfactory but at the short waves is seriously interfered with by the presence of the operator's hands or body near the grid terminal leading to the detector control cabinet. Receiving set No.1922-Z suffers more seriously from this difficulty than does No. 1922-Y, while No. 1922-W, because of its lack of shielding of the high radio-frequency voltage leads, is somewhat more difficult to control, although for the longer wave lengths it is quite usable.

As for the stability of regeneration, this is almost entirely dependent upon the use of a grid bias instead of a grid leak and grid condenser as is exemplified in receiving set No. 1922-XX which is extremely free from any tendency to start or stop oscillation with strong "static" discharge or sudden variation in signal intensity. It is to be remembered, however, that since the degree of regeneration for this type of connection is considerably less than that possible when a grid leak and grid condenser are used, stability of regeneration can only be secured at some sacrifice of sensitivity. This grid condenser and leak type of detection has been used in the design of receiving set Nos. 1922-X and 1922-XX while in the Nos. 1922-Y and 1922-Z the method of grid connection is left to the user, since any type of electron tube apparatus may be used with these receiving sets. In the electron tube control boxes supplied by the manufacturers of these two receiving sets a grid leak is used so that a superior degree of regeneration is possible, but not without the consequent reduction of stability. In general all of these receiving sets, with the exception of No. 1922-W, show great ease of control particularly in so far as the functions of the various controls are independent of one another. In No. 1922-W this lack of independence of control is strongly evident in the interaction of the operation of the several coupling systems. It is found, for instance, that a change in the coupling between the secondary and primary circuit is accompanied by a considerable change in the wave frequency (wave length) of one or both of these circuits and when undamped reception is being accomplished, the consequent change in the beat note is so much that under certain conditions it may become inaudible. A similar change is noted in the operation of the plate circuit coupling and where continuous wave reception is to be accomplished on high wave frequencies

(short wave lengths), it is only by successive readjustments of the constants of the circuit after each change in coupling is made, that it is possible to operate the receiving set for best reception.

Appendix

Data on Electron Tubes Used in this Test.

In securing the data given in this report the electron tubes used were either those submitted by the manufacturers or were of the type specified. Effort has been made to use tubes typical of the kind specified but those commercially available of a given type differ from one another to a considerable extent. It has been considered advisable, therefore, to append to this report a statement of certain properties of the tubes used in these receiving sets.

In Table 13 are given the arbitrary designation numbers of the tubes used with the five receiving sets, together with statements of the conditions under which the tubes were used.

In Figs. 13 to 17 inclusive are shown the relations between input radio-frequency and output audio-frequency voltages for the tubes used with these receiving sets.

It is to be borne in mind that both the selectivity and sensitivity of the receiving set depend in part upon the characteristics given in these curves.

It is impossible, however, to determine the relative selectivities and sensitivities from these data since in each of the receiving sets investigated there was a considerable degree of inherent regeneration, the effect of which on the selectivity and sensitivity cannot be easily calculated.

It is to be concluded, however, that the values of sharpness of resonance and sensitivity given in Tables 7 to 12 inclusive will be obtained whenever the receiving sets are used with tubes having the characteristics here given.

A detailed description of methods used in measuring properties of electron tubes is given in Bureau of Standards Letter Circular No. 87.

Table 13.

Data on Electron Tubes.

Receiving Set No.	Electron Tube	Filament Current, Amperes.	Plate Voltage, Volts	Grid Condenser, Capacity uuf	Grid Leak Megohms
1922-W	R3822	0.98	42.0	500	3.7
	R2495	1.00	40.0	500	4.0
1922-X	R2495	1.00	40.0	170	4.0
1922-Y	R3378	0.65	40.0	350	0.65
1922-Z	R2614	0.60	40.0	350	0.42
1922-XX	R2614	0.65	40.00	-	Bias

Legends for Figures.

Fig. 1. Circuit diagram of receiving set No. 1922-W.

" 2. " " " " " " 1922-X.

" 3. " " " " " " 1922-Y.

" 4. " " " " " " 1922-Z.

" 5. " " " " " " 1922-XX.

" 6. Circuit diagram of apparatus used in sensitivity measurements.

" 7. Circuit diagram of apparatus used in sêlectivity measurements.

" 8. Resonance curve of receiving set No. 1922-W.
a. 1000 meters. Low antenna resistance.
b. 1000 meters. High antenna resistance.
c. 2500 meters. Low antenna resistance.
d. 5000 meters. Low antenna resistance.

" 9. Resonance curve of receiving set No. 1922-X.
a. 1000 meters. Low antenna resistance.
b. 1000 meters. High antenna resistance.
c. 2500 meters. Low antenna resistance.
d. 5000 meters. Low antenna resistance.

" 10. Resonance curve of receiving set No. 1922-Y.
a. 1000 meters. Low antenna resistance.
b. 1000 meters. High antenna resistance.
c. 2500 meters. Low antenna resistance.
d. 5000 meters. Low antenna resistance.

" 11. Resonance curve of receiving set No. 1922-Z.
a. 1000 meters. Low antenna resistance.
b. 1000 meters. High antenna resistance.
c. 2500 meters. Low antenna resistance.
d. 5000 meters. Low antenna resistance.

" 12. Resonance curve of receiving set No. 1922-XX.
a. 1000 meters. Low antenna resistance.
b. 1000 meters. High antenna resistance.
c. 2500 meters. Low antenna resistance.
d. 5000 meters. Low antenna resistance.

" 13. Characteristic curves of electron tube No. R2614 with grid bias.

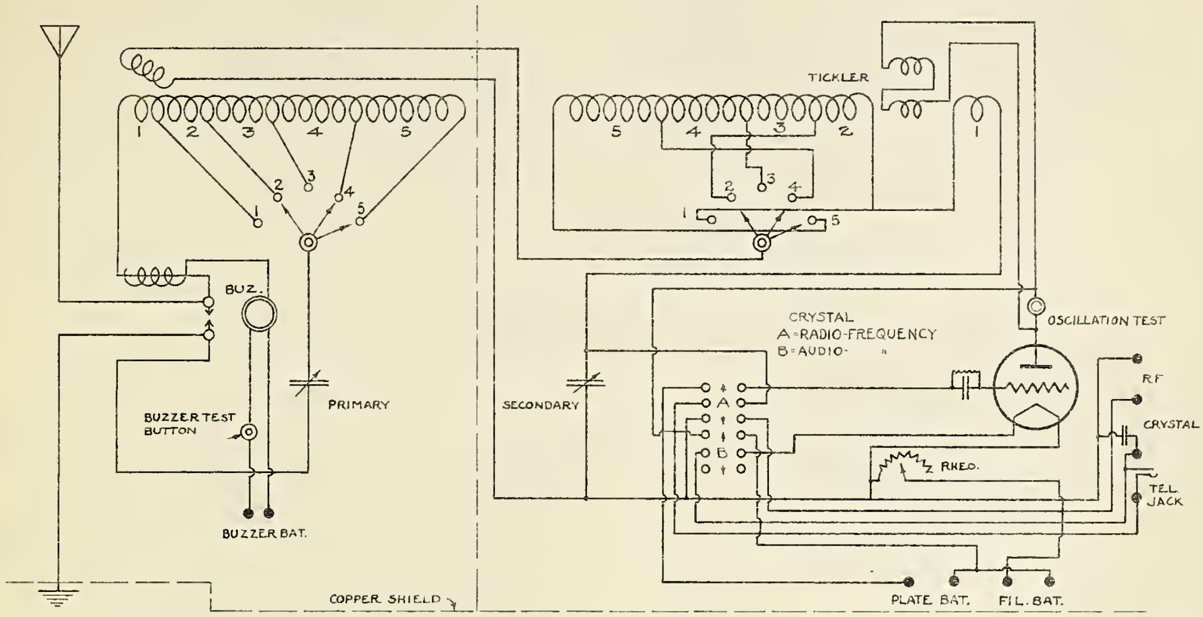
Fig. 14. Characteristic curves of electron tube No. R2822.

" 15. Characteristic curves of electron tube No. R2495.

" 16. Characteristic curves of electron tube No. R2495

" 17. Characteristic curves of electron tube No. R2614 with grid condenser and leak.

Department of Commerce,
Washington, D.C.



(Fig. 2.)

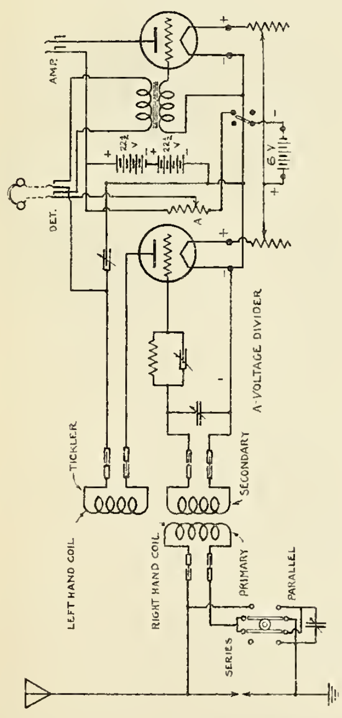


Fig. 1.

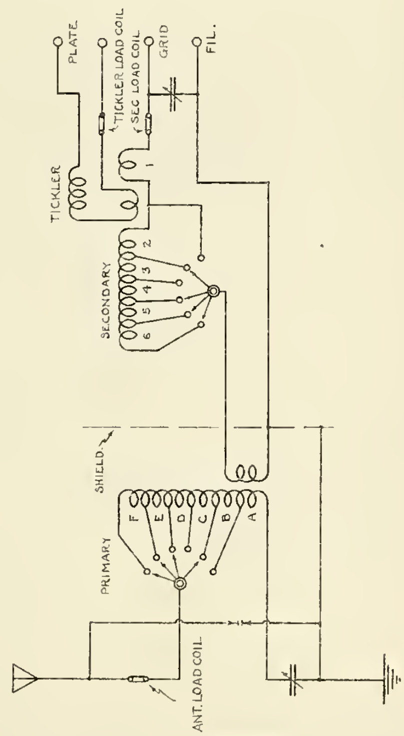
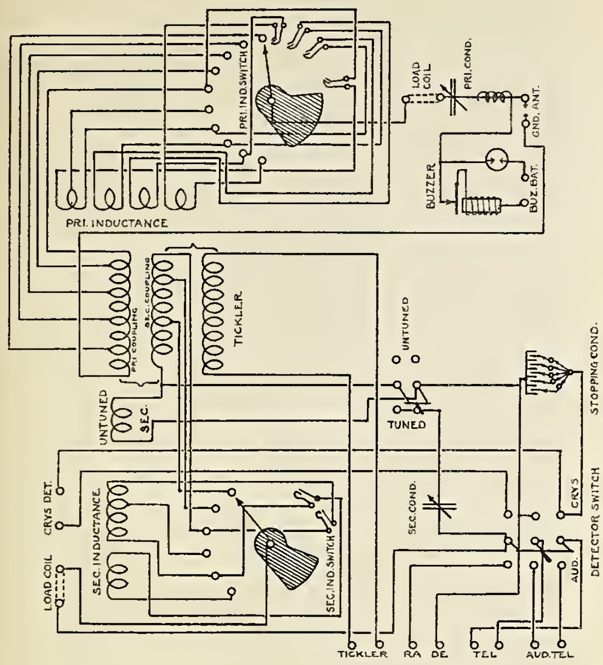


Fig. 3.



(Fig. 4.) Radio No. 896-D

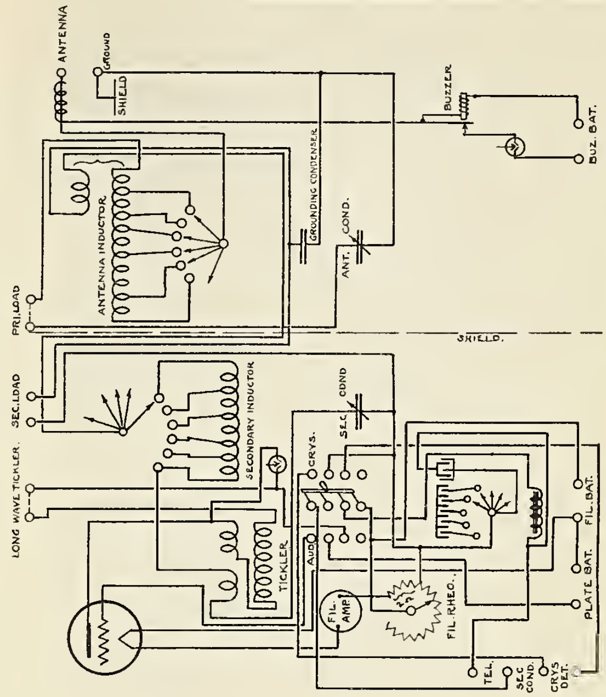


Fig. 5.

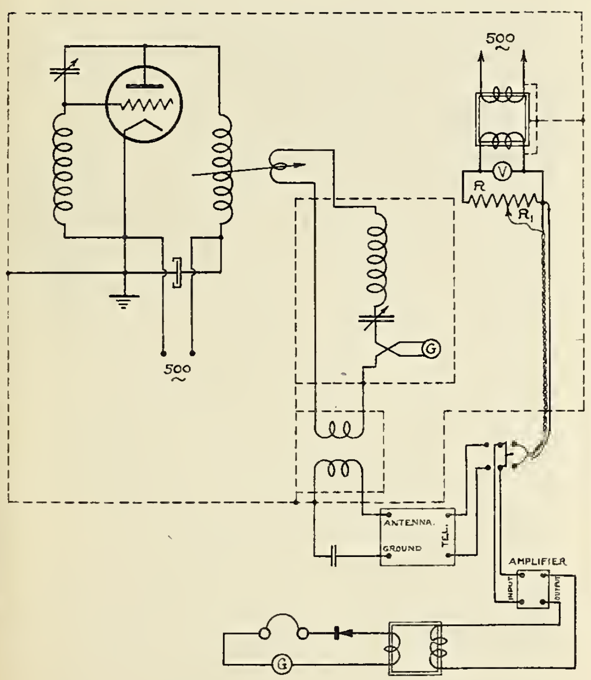


Fig. 6.

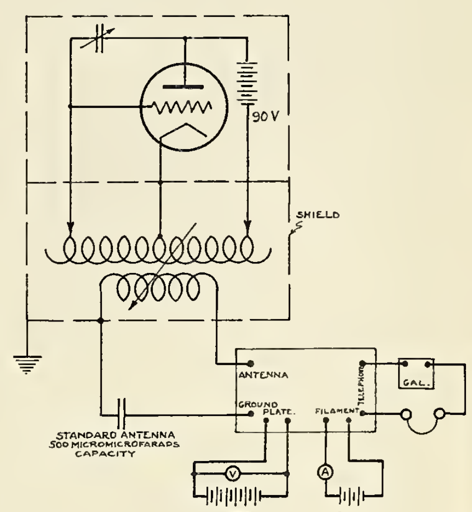
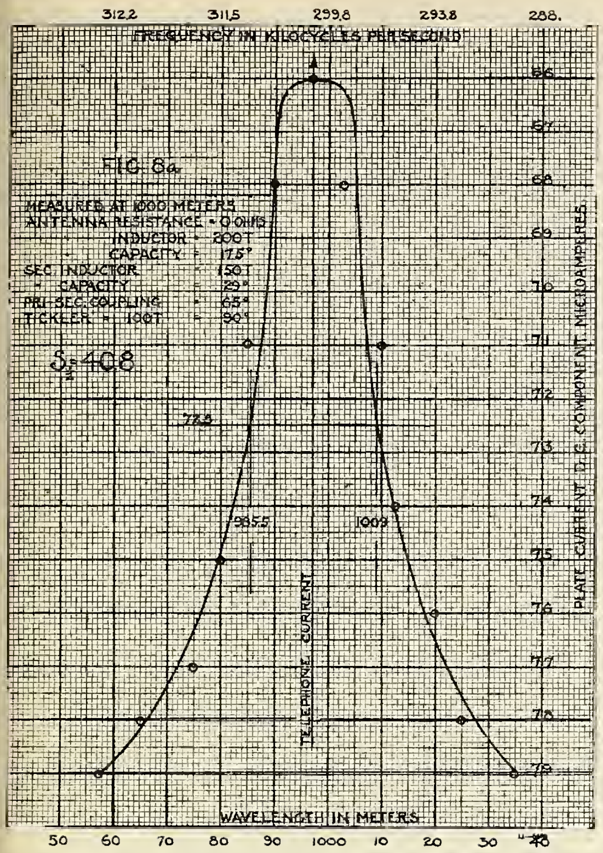


Fig. 7



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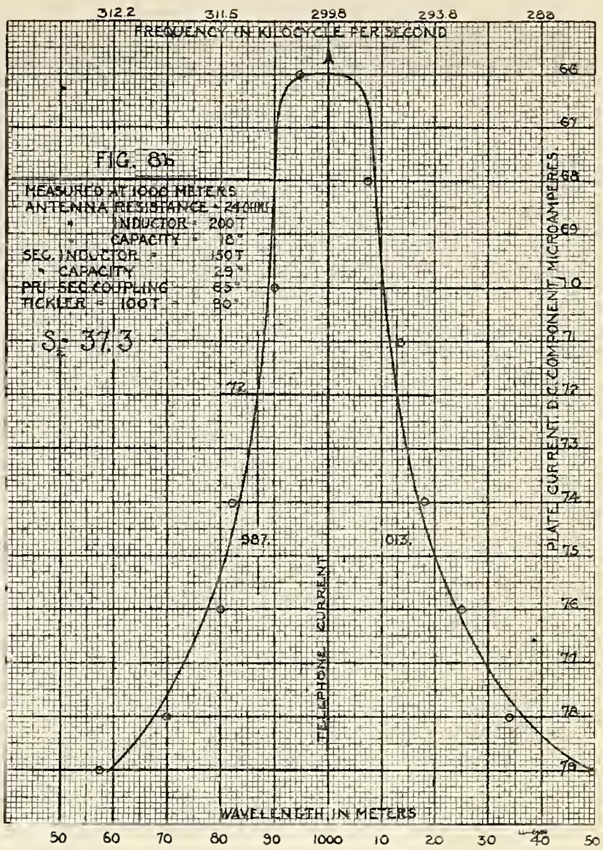

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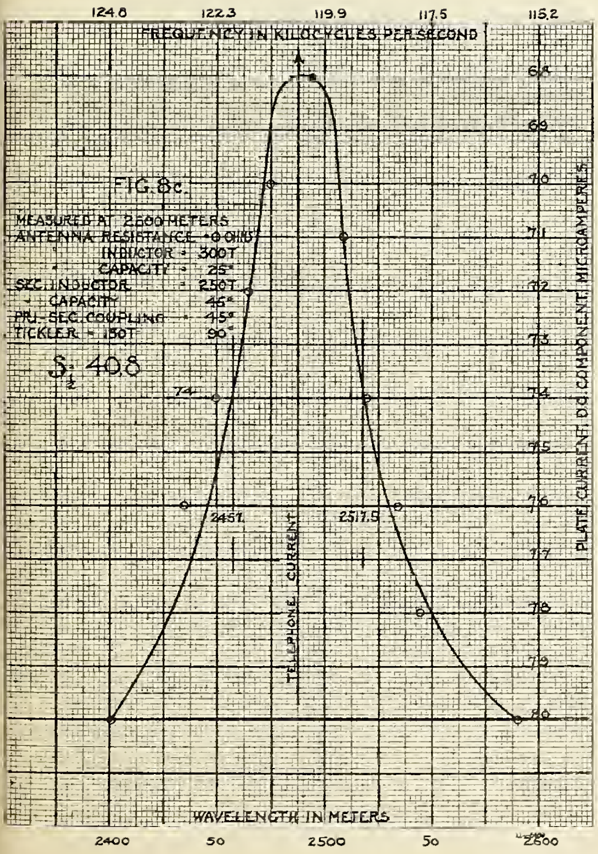

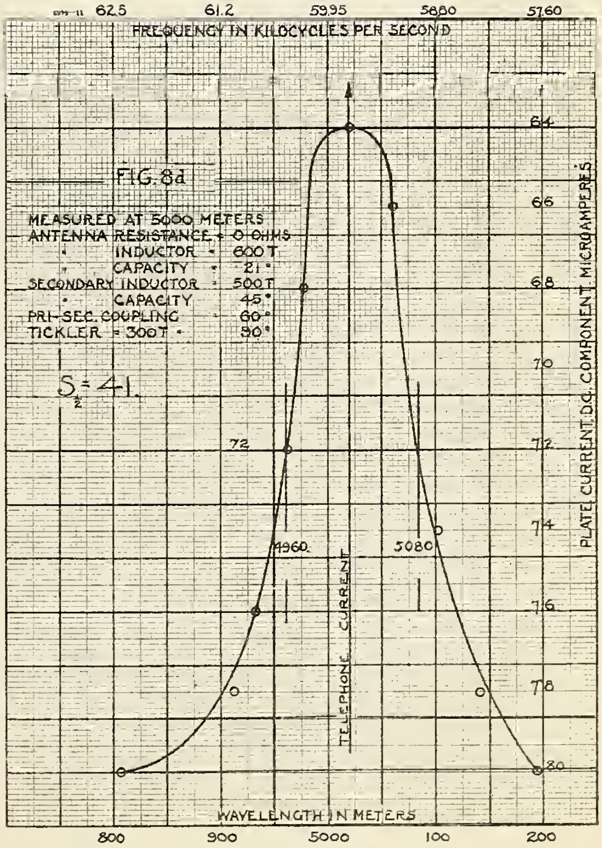

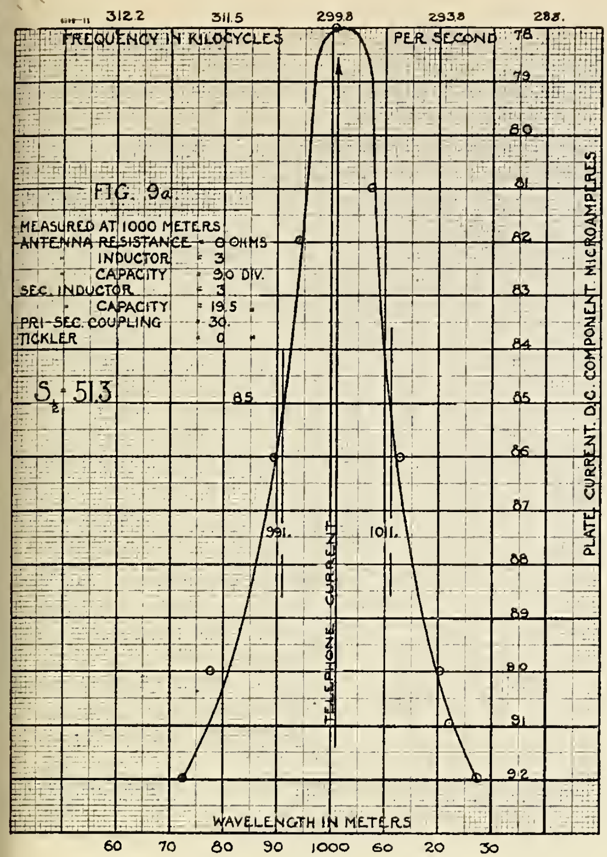

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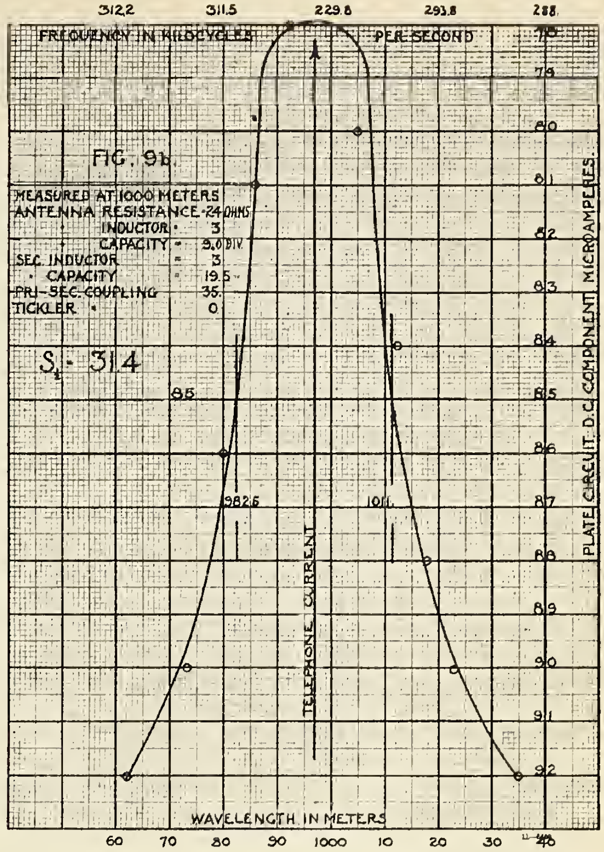

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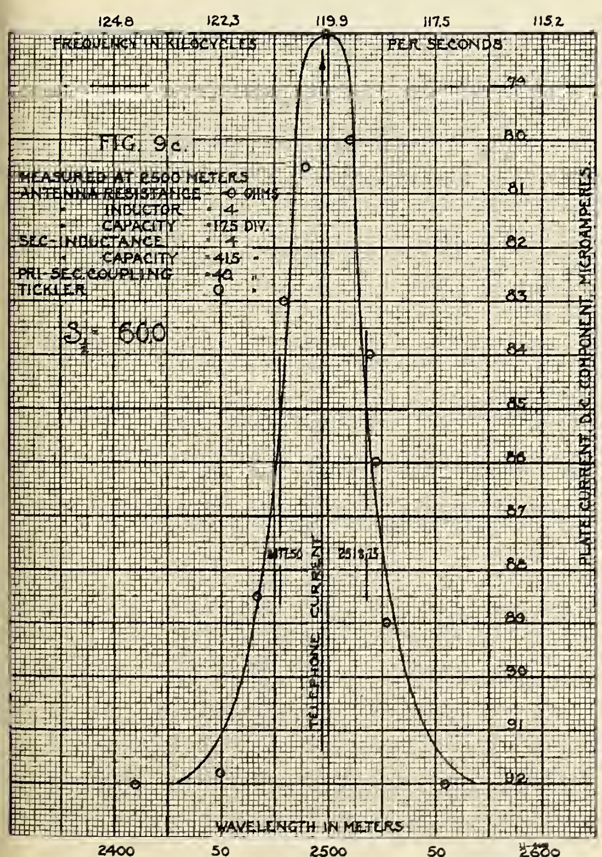

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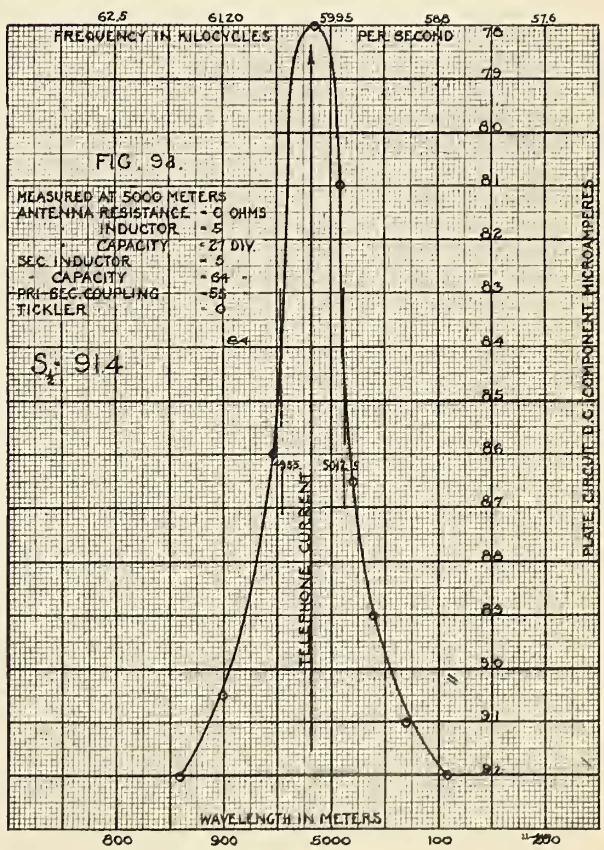

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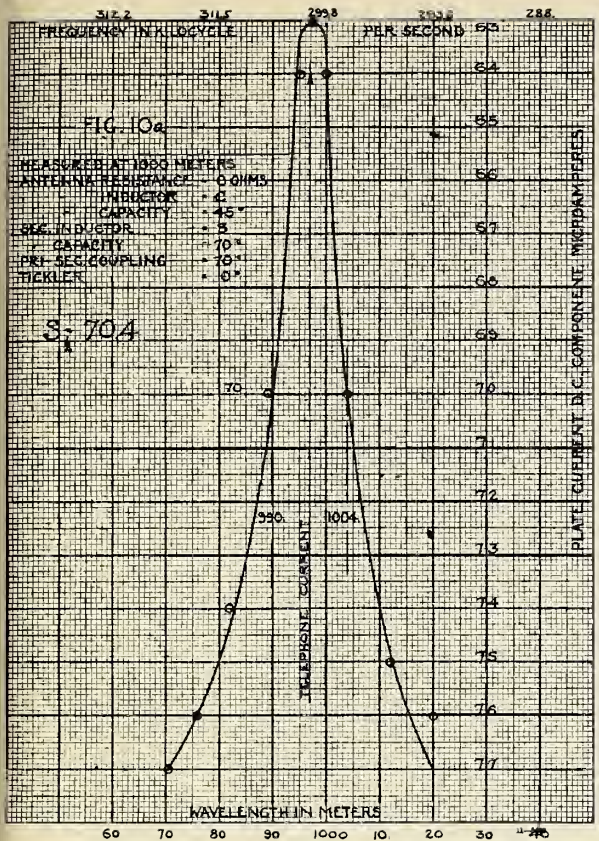

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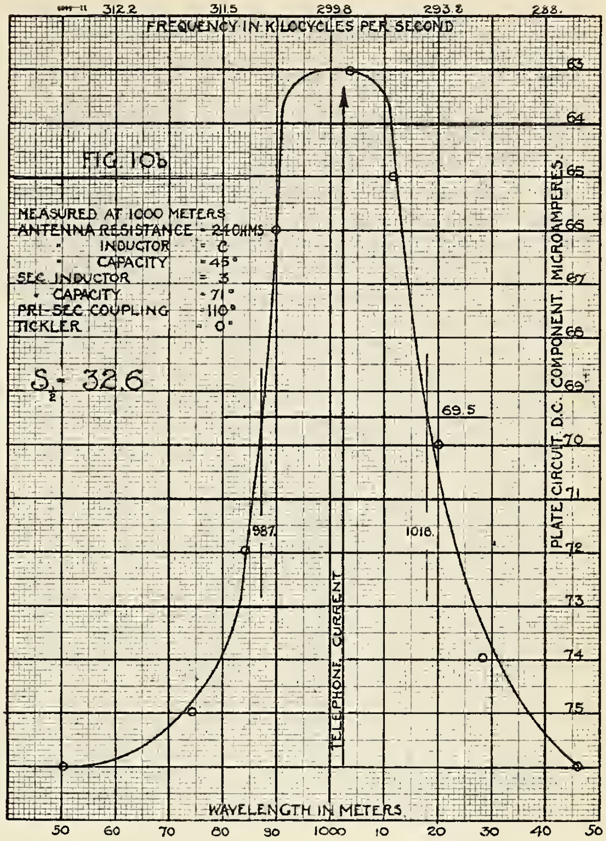

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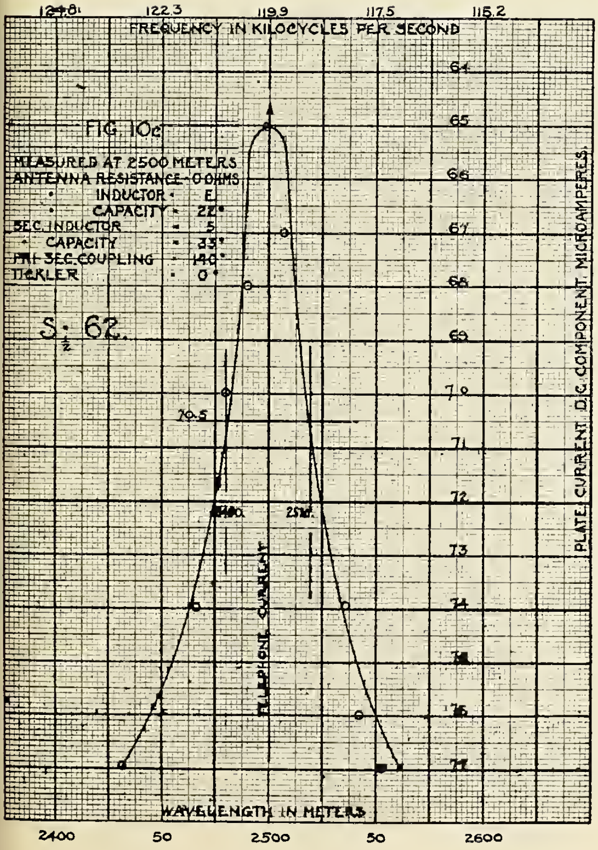
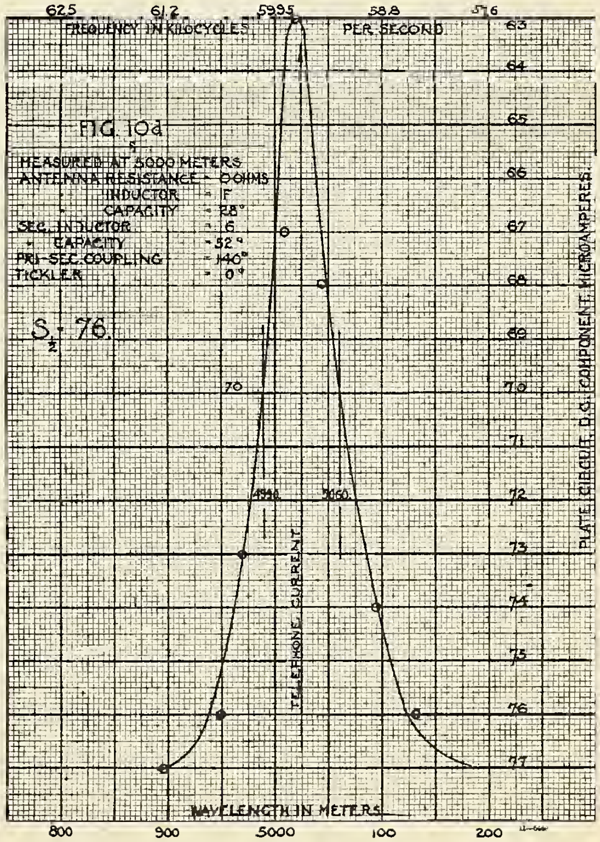


Radio No 897-K



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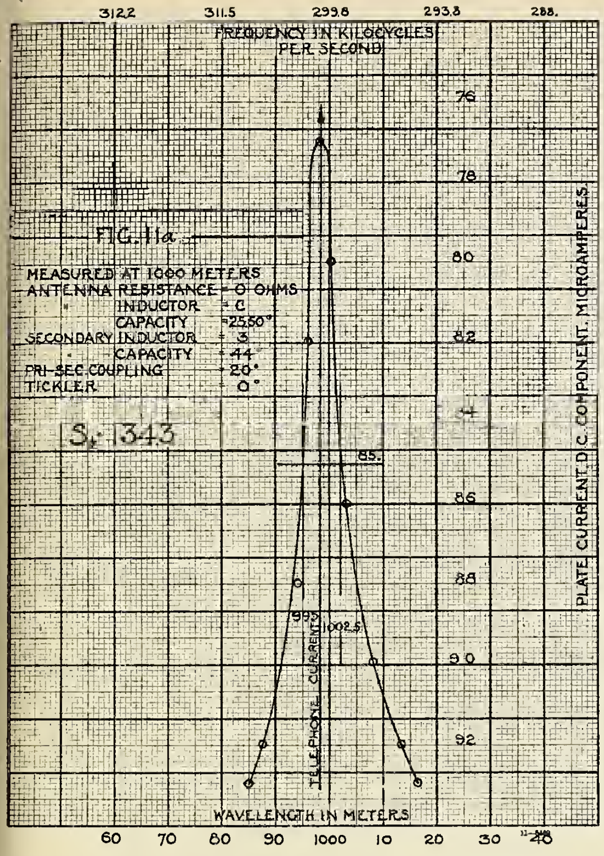

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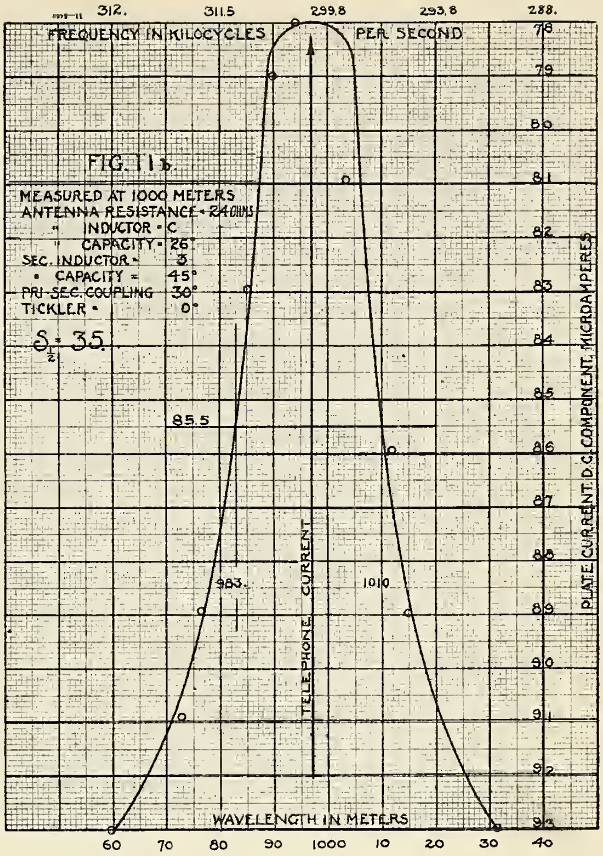

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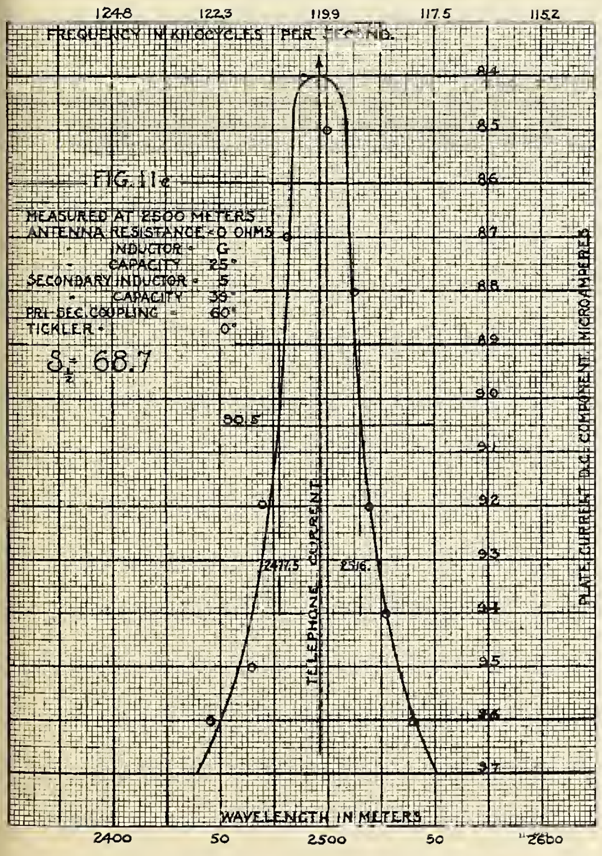

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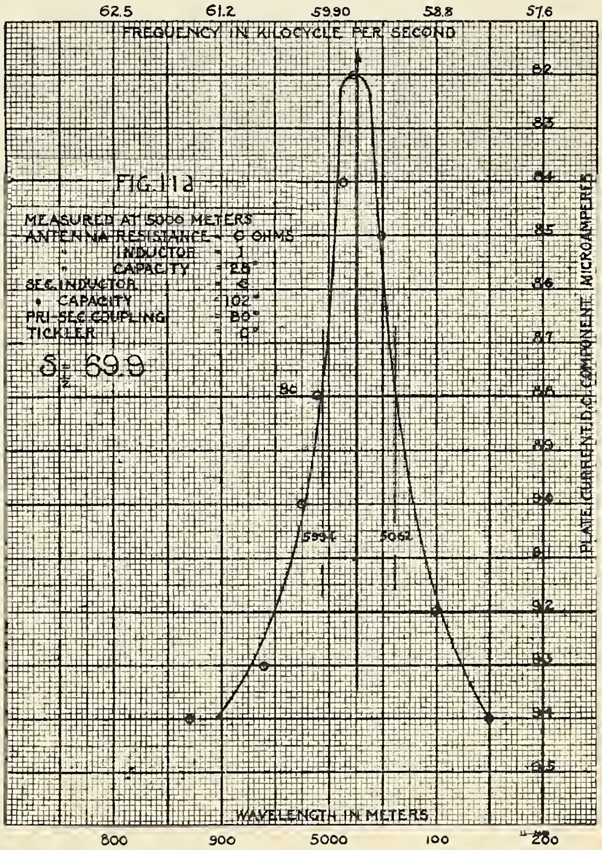

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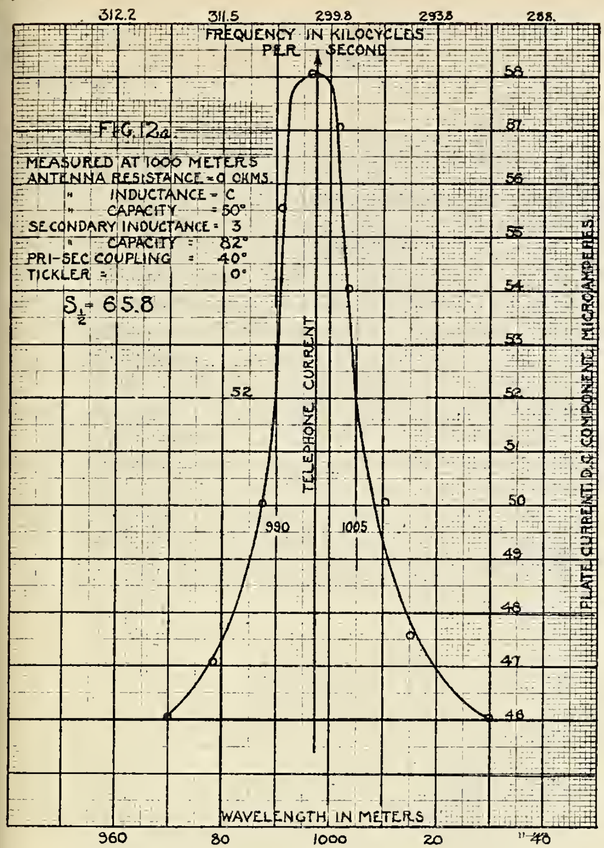

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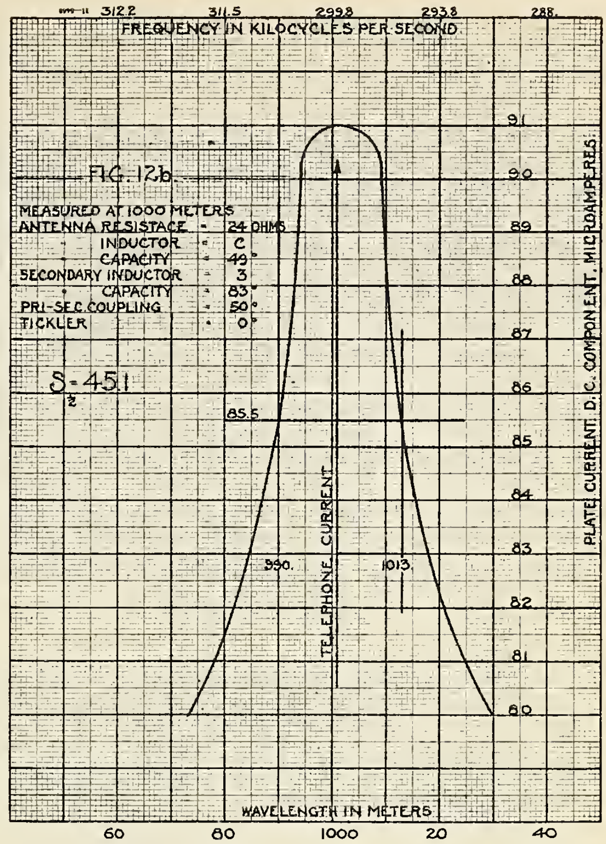

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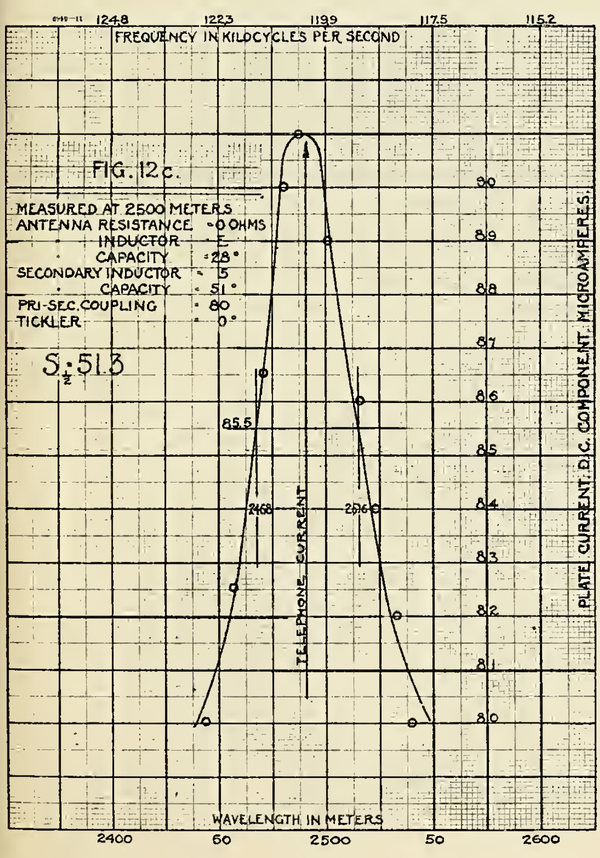

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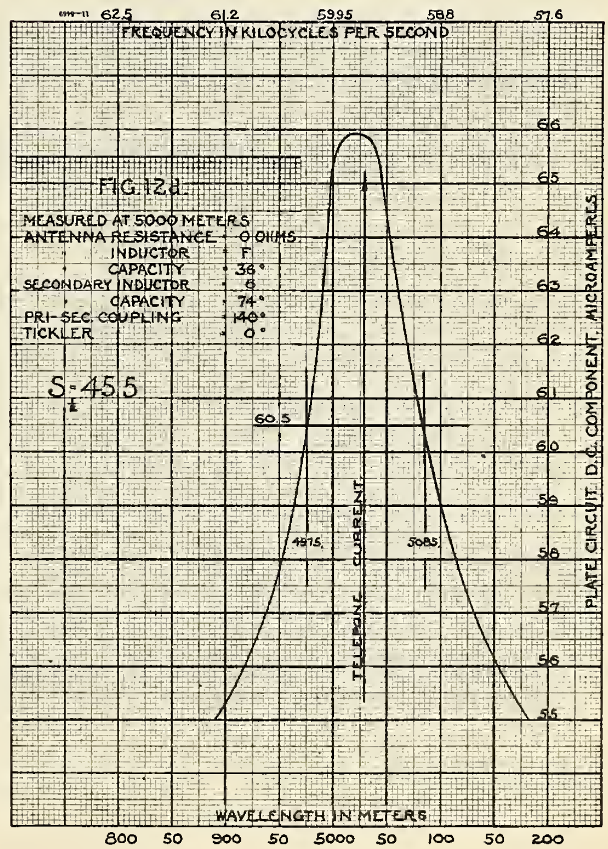

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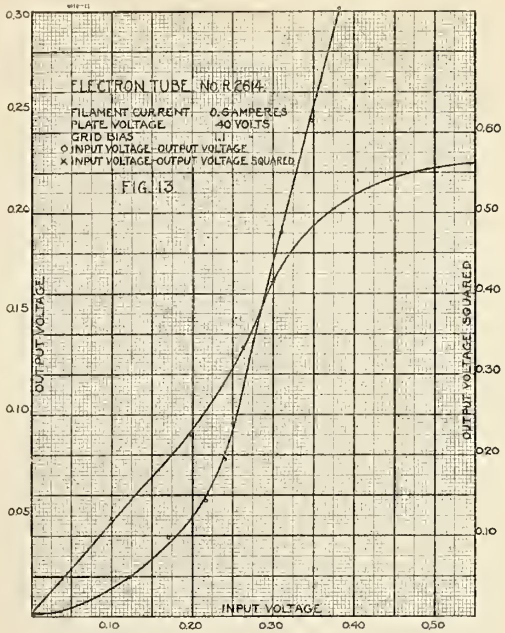

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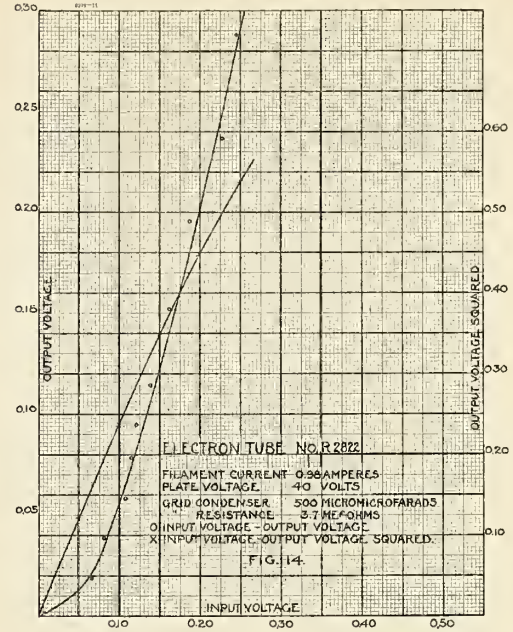

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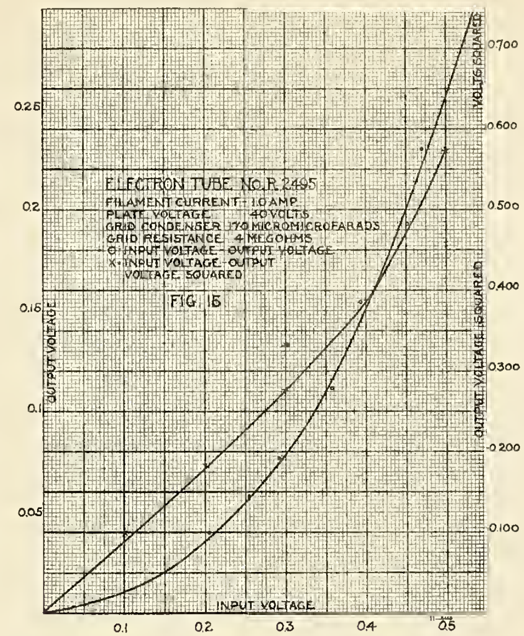

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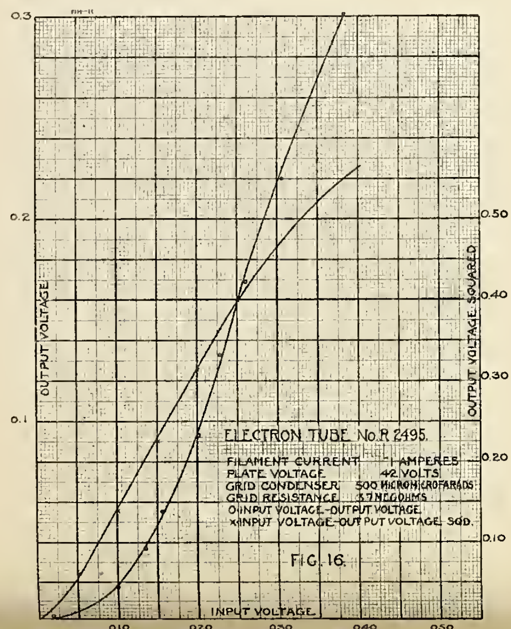

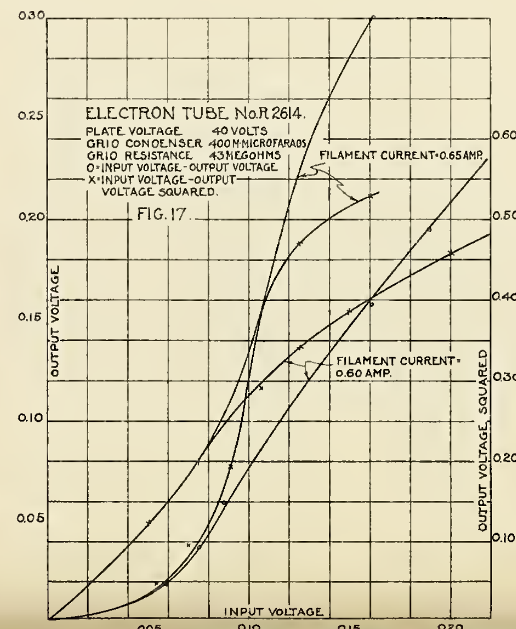

Barrett